DOCUMENT RESUME

ED 184 849 SE 030 494

AUTHOR Holliday, William G.
TITLE Overprompting Science Students Using Adjunct Study Questions.
SPONS AGENCY Alberta Advisory Committee on Educational Research, Edmonton.; Calgary Univ. (Alberta).
PUB DATE Apr 80
NOTE 18p.; Paper presented at the annual meeting of the National Association for Research in Science Teaching (53rd, Boston, MA, April 11-13, 1980).

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS *Educational Research; *Models; *Questioning Techniques; Science Instruction; Secondary Education; Secondary School Science; Student Evaluation; *Teaching Methods
IDENTIFIERS *Adjunct Questions

ABSTRACT

Described is an investigation of the hypothesis that students presented with strong hints or prompts to answers of comprehension questions adjunct to a flow diagram would understand less than students presented with no prompts. Also described is the study of the hypotheses that a diagram-only treatment group would outperform the prompted group and all treatment groups would outperform a placebo-control group. The research, based on the selective attention model, is described as supportive of the model, and recommends an instructional goal for teachers. (SA)

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# Overprompting Science Students Using Adjunct Study Questions

William G. Holliday

University of Calgary

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This study was supported in part by provincial funds administered through the Alberta Advisory Committee for Educational Research and the University Grants Committee.

NARST paper, Boston, April 1980

SE 030 494

Abstract

The selective attention model often used to explain the effects of study questions adjunct to learning materials in other science education studies also suggested that strongly prompting students to the answers of such questions was less effective than an unprompted adjunct question treatment. This hypothesis was supported ($p < .05$) by an experiment using a complex flow diagram displaying scientific cyclical schema. Tenth grade students were randomly assigned to an unprompted-question, no-question, prompted-question and a placebo-control group. The no-question treatment did not significantly outperform the prompted treatment, as predicted by the model. The information presented in the flow diagram was operationally defined and related to comprehension adjunct and posttest questions. The theoretical discussion and the present findings suggested that science teachers should use prompting techniques with extreme caution.

# Overprompting Science Students Using Adjunct Study Questions

During the past 15 years, numerous experimental studies (Markle and Capie, 1976; Rickards, 1979; Wilson and Koran, 1976) have explored the facilitory and inhibitory learning effects of study questions adjunct to science and nonscience prose passages and have explained these findings in terms of a selective attention model (Anderson, 1970; McConkie, 1977; Wittrock and Lumsdaine, 1977). On the one hand, facilitory hypotheses derived from this model predicted that some adjunct questions focused students' attention on the questioned information presented in the passages. On the other hand, inhibitory hypotheses predicted that other adjunct question treatments interfered with learning, either when questions specifically diverted students' attention away from non-questioned information or when questions generally reduced students' attention by strongly or mildly suggesting, hinting or "overprompting" the physical locations of desired answers in the passage. There are two forms of overprompting found in science classroom materials. First, a common strong prompting technique consists of underlining or bold printing desired responses to verbatim (i.e., word-by-word), transformed verbatim (i.e., rearranging substantive passage words) or comprehensive style questions. Second, a milder prompting technique often consists of issuing either verbatim or transformed verbatim questions without underlining or bold printing target answers. Anderson (1970) theorized that such overprompting techniques reduced student searching or inspection behavior

of prose materials, resulting in little meaningful attention to queried information. Previous studies (Anderson and Faust, 1967; Anderson, Faust and Roderick, 1968; Faust and Anderson, 1967) exploring strong prompting mechanisms described in inhibitory overprompting hypotheses were limited to the learning (under "uncontrolled" conditions) of rote memorized information presented in a prose passage format using verbatim questions. The purpose of this selective attentional study was to evaluate (under controlled conditions) learning effects of a strong prompting technique on a complex flow diagram describing scientific pathways and cyclical schema in terms of comprehension adjunct and posttest questions. Earlier studies (Holliday, 1976, in press; Holliday, Brunner and Donais, 1977; Holliday, Whittaker and Loose, 1978) in this series have evaluated other attention hypotheses using variations of the same diagrams and similar comprehension questions. In this regard, Wilson and Koran (1976) encouraged the investigation of adjunct questions and their effects on specialized learning materials in science, while Anderson (1972) encouraged the use of operationally definable comprehension questions in such studies.

Evidence supporting the selective attention model initially came from paired associate research investigating cue selection. For instance, Underwood, Ham and Ekstrand (1962) showed that students recalled more trigrams (e.g., CFB, TND) printed on distinctive colored backgrounds when tested using the many distinctive backgrounds in the response mode rather than when tested using a single white background. Apparently, students linked the trigram letters to the unique colored backgrounds rather than memorizing the trigrams independent of the colors. Later, Duell (1967) found that kindergarten children also selectively attended to irrelevant

cues under overprompting conditions and did not necessarily process all the critical information. In one experiment, children learning eight words were presented with a prompted instruction (i.e., words paired with their pictures) followed either by the same prompted instruction or unprompted instruction (words only). The unprompted group learned four times as many words compared to the prompted group. Duell concluded that children in the prompted group could respond correctly to the sight vocabulary task by referring to the pictures alone. In contrast, the children performing the task in the unprompted group had to focus attention on the word because no adjunct picture was available. The Underwood and Duell studies described here established the foundation for executing school-related prompting experiments evaluating the generalizability of the selective attention model.

Anderson et al. (1967), Faust et al. (1967) and Anderson et al. (1968) using classroom prose materials investigated a strong prompting procedure employed in some self-instructional programs to assist students in locating correct answers before responding to programmed verbatim questions. The following science example (Biological Sciences Curriculum Study. 1965) of a verbatim adjunct question has been used by others to illustrate an obvious case of strong overprompting:

When an egg is released from the ovary, the wall of the uterus is thin.

When an egg is _____ from the ovary, the wall of the uterus is ____.

Anderson and others questioned the effectiveness of these B.S.C.S. self-paced materials and evaluated an assumption often associated with the development of such heavily-prompted programmed frames. The assumption (cf. Cook, 1963) was that learners' attention should be concentrated on

the cue word(s) in the question and associatively linked to the correct response word(s) and that overprompting seldom was a problem. Indeed, the problem with this line of reasoning was that students sometimes failed to notice in a meaningful fashion the cue words in the question because the target response was too easily located by the student in the passage and often without understanding the question content in the first place, resulting in few cue-response linkages. Collectively these earlier studies reported that strongly prompted versions of programmed materials resulted in lower recall scores compared to unprompted versions. Unfortunately, control groups such as reading-only and placebo conditions were not employed and prevented the establishment of baseline performance levels - an essential ingredient in any adjunct question study, according to Faw and Waller (1976).

The present study investigated the hypothesis that students presented with strong prompts or hints to the answers of comprehension questions adjunct to a flow diagram would comprehend less than students provided with a no-prompt condition. Furthermore, a diagram-only (no adjunct questions) treatment group was hypothesized to outperform the strongly prompted treatment. In addition, all treatment groups were hypothesized to outperform a placebo-control group. Students provided with adjunct questions in this study were permitted to review the information presented in the flow diagram, a condition consistent with classroom practice and inconsistent with many recent experiments exploring other cognitive process issues dealing with shaping students' behaviors (Rickards, 1979).

## METHOD

Subjects. Students used in this experiment were enrolled in high school biology classes, spoke English, were middle-class, numbered 170, lived in

Calgary, Alberta and ranged in ages from 14-16.

Design and Procedure. Subjects were randomly assigned to three treatment conditions and a single control. The four groups studied the different learning materials and responded to a posttest, thus creating a posttest-only equivalent group design. Students were told that "a 30-question multiple-choice test containing only words would be administered to the entire class after the study period and that they should take plenty of time to learn the self-instructional material before them."

Materials. The control group was provided with a science placebo prose passage. The three treatment groups were provided with a picture-word diagram (see Holliday et al., 1977) describing biogeochemical cycles taught to these tenth-grade students. First, the unprompted-question group received the diagram and 20 adjunct questions requiring 42 answers. Second, the prompted-question group received the same materials with added prompts displayed in the diagram. The prompts consisted of 42 printed numbers displayed in the diagram and in each case adjacent to the verbal label(s) constituting the answer to an adjunct question with the same assigned number. For example, the first adjunct question asked, "List four things that need oxygen." The question number appeared in the diagram before the verbal labels, "tree", "car", "factory" and "deer". Third, the no-question group received the flow diagram without prompts or adjunct questions.

The single flow diagram used in this study was somewhat more complex than those found in typical high school biology textbooks (cf. Otto and Towle, 1977) and also was used in a concurrent study (Holliday, in press) dealing with question pacing and frequency. Recently Winn (in press a and b)

empirically and theoretically supported the learning effectiveness of analogous science diagrams. The present diagram presented four-related cycles by syntactically condensing prose material often present in a textual format. The pathways included oxygen, carbon dioxide, nitrogen and the water cycle and were chosen because they lent themselves to a diagrammatic instructional medium. Arrowed lines, separation and adjacency, and verbal labels and their referent drawings constituted the spatial or diagrammatic techniques used to facilitate student learning of the illustrated conceptual relationships. A textual description of the same linkages typically would be restricted to the use of nouns, verbs and modifiers presented in sentence form. The experimental diagram used in the present study contained conceptual labels, such as "nitrifying bacteria" and "nitrate" spatially linked in the display by arrowed lines, forming part of the nitrogen cycle. The diagram also contained colored, stylized line drawings illustrating concrete concepts (e.g., "deer"). The more abstract technical concepts (e.g., "nitrate") were placed in a logical position similar to their occurrence in nature. For example, the "nitrifying bacteria" label was spatially placed below ground level.

The comprehension adjunct and posttest questions used in this study were operationally definable in terms of each other and in terms of the treatment learning materials, as outlined by Anderson (1972) and employed in a recent adjunct question study (Threadgill, 1979). Specifically, the comprehension adjunct questions were of two types and asked students to write concept labels associated with a given concept displayed in the flow diagram. Ten type I questions asked students "What" single component of a two-concept pair linked by an arrowed line constituted the correct

response. For example, the question "What thing makes oxygen?" asked students to write the concept label ("tree", in this case) associated with the given concept ("oxygen"). Ten Type II questions asked students to "List" two to seven components independently linked by arrowed lines to a central or common concept presented in the diagram. For example, the question, "List four things that need oxygen" asked students to write the concept labels associatively found in the diagram. These two types of questions were positioned in a random presentation order on a sheet of paper. The questions were placed in a logical sequence and were independent of each other in terms of content and type. Feedback to students regarding answer correctness was not provided as is the case in recent adjunct question studies.

The comprehension posttest questions consisted of 30 four-choice items and constituted a content synthesis of two or more of the adjunct questioned information units displayed in the diagram. For example, "Trees can: (1) add oxygen to the air, (2) remove carbon dioxide from the air, (3) remove oxygen from the air, or (4) all of the above". A paraphrasing technique adapted from Anderson and Biddle (1975) was used to increase the chances of measuring learner comprehension of the diagrammatic information. Specifically, the verbs and modifiers differed in the adjunct and posttest questions and, of course, were not used in the diagram. The nouns used in the question and diagram were identical because of the lack of reasonable substitutes, as is often the case (cf. Anderson, 1972). The use of such paraphrasing techniques minimized the overlap of substantive words throughout the experiment, thereby increasing the likelihood of the questions measuring semantic encoding or comprehension and not just verbatim perceptual or acoustical encoding of

surface information, that is the learning of meaningless strings of word shapes and speech sounds. as described by Anderson et al. (1975) and Bormuth (1970).

## RESULTS

The Student Newman-Keuls multiple range procedure ($p<.05$) was used to evaluate the significant differences among the mean scores of the four groups. As predicted, the unprompted group outperformed the prompted question group which, in turn, outperformed the control group. On the other hand, the no-question group failed to outperform the prompted group (see Table I). Internal consistency or reliability (Cronbach's alpha) of the posttest instrument was 0.82. Of course, an overall analysis of variance test was used to establish the legitimacy of using this multiple range test, $F(3, 166) = 21.90$, $p<.05$.

Place Table 1 about here

## DISCUSSION

The findings supported the most important hypothesized group difference: the heavily prompted version was less effective than the unprompted version. These results were consistent with the cited self-paced programmed studies (Anderson et al., 1967; Faust et al., 1967; and Anderson et al., 1968) and the cited theoretical discussions, (Anderson, 1970; McConkie, 1977; Wittrock et al., 1977) describing a selective attention model dealing in part with the strong and mild overprompting of desired responses to study questions adjunct to learning materials. First, the model suggested that students who received the unprompted-question treatment were forced to read each question carefully and search the diagram for the correct answer to

each question, thus increasing the likelihood of meaningful attention and comprehension. Second, this model suggested that students in the present study who received the strongly prompted question treatment repeatedly encountered printed numbers in the diagram adjacent to verbal labels. As students responded to the adjunct questions, many learners discovered that these numbers were next to the labels constituting th answers to the questions assigned to the same number. Consequently, these students likely shortcutted the read-and-search-for-the-answer method of responding when they discovered that the adjunct questions could be answered more easily by merely locating in the diagram the printed numbers corresponding to question numbers and by responding to each question on this basis. Perhaps this counter-productive shortcut method of answering questions would have been easier for students than carefully reading each question and searching for the appropriate verbal label answers printed in the diagram. In this regard, Anderson's (1970) analysis of the selective attention model states that students tend to follow the path of least effort and answer adjunct questions using the easiest possible method. Indeed, even "motivated" students process only selective information and often fail to pay attention and comprehend the total information contained in question-answer complexes. Anderson concluded his discussion on selective attention by recommending that teachers use questions that force students to pay attention and comprehend all critical information. The findings of the present study reinforce this recommendation in terms of the described experimental conditions.

Third, the model suggested that a no-question treatment would result in higher posttest scores than a prompted-question treatment, providing

this latter treatment discouraged student searching for target answers presented in the diagram. However, this hypothesis was not supported (nor rejected) by the data generated in the present study. Perhaps, students in the prompted-question group were exposed to enough diagrammed relationships, while searching for the 42 answers or question numbers, that these learners attended and semantically processed the criterial conceptual linkages to a degree "equivalent" to the no-question group. Clearly, both groups learned information from the diagram, as suggested by the scores generated by the placebo-control group. Indeed, this latter finding essentially eliminated the possibility that the prompted-question group did not process some of the diagrammatic information. Most other question experiments reported during the past 15 years did not include a control group, thus leaving open to question the learning effects of various question and reading-only (no question) treatments (Faw et al., 1976; Rickards, 1979). The present data clarified the fact that students can learn some information even under overprompted conditions. Yet, it is important not to overgeneralize beyond the conditions of such question experiments (cf. Markle et al., 1976).

Milder versions of overprompting also occur in today's science classrooms and include the use of verbatim and transformed verbatim study questions so often found at the end of textbook chapters. Future attentional research work in science education should concentrate on the effectiveness of these question types. Anderson (1972) argues that answering such overprompted questions (even without employing strong prompting systems) requires little thought and does not constitute evidence of learner comprehension of textbook information. Yet, these questions are often used in the classroom.. Unfortunately, verbatim style questions can be answered with a minimal of attentional coordination

between cued and response "surface information" (cf. Chomsky, 1965), resulting in the learning of strings of word shapes and of word sounds, but not necessarily the learning of word meanings (Anderson and Biddle, 1975). Furthermore, research suggests that students can answer verbatim style questions without decoding and comprehending the presented information. For example, Holliday et al. (1978) reported,in an aptitude treatment interaction (ATI) study dealing with non-diagrammatic displays,that verbatim questions apparently inhibited the comprehension of an adjunct prose passage describing fossils, especially in low verbal students. In contrast, a prose-without-questions treatment resulted in higher posttest scores. The presumption was that many low verbal students thought that merely copying an answer from the adjunct text to the response blank provided on the verbatim question sheet constituted an adequate method of preparing for the posttest when, in fact, a no-question text-only treatment constituted a more powerful learning medium in terms of visual comprehension of the verbally described fossils. This recent research in science education, the present study, and earlier work lend support to the selective attention model as a reliable source of supportable hypotheses and to Anderson's (1970; 1972) contention that a chief instructional goal is to arrange and organize learning materials so as to force students to do all of the attentional processing necessary for the comprehension of science information.

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TABLE I

Observed Cell Means and Standard Deviation
on the Comprehension Test

| Group | n | Mean | S.D. |
|---|---|---|---|
| Unprompted-question | 44 | 19.25 | 4.4 |
| No-question | 41 | 17.98 | 3.8 |
| Prompted-question | 40 | 16.53 | 3.4 |
| Control | 45 | 13.04 | 3.6 |